Improvement in the Accuracy of the New Broadband Square Law Detector

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Broadband square law detectors are required for precision power measurements and a wide variety of other detector applications. The new square law detector, developed and reported earlier, has a wider dynamic range and a more accurate square law response than that available in the past. Other desirable characteristics are high-level dc output with immunity to ground loop problems, fast response times, ability to insert known time constants, and good thermal stability. This article reports on further development work and shows how the new detector can be operated in a programmable system with a ten-fold increase in accuracy.

I. Introduction

Broadband square law detectors are required for precision power measurements and a wide variety of other detector applications such as the Noise-Adding Radiometer (Ref. 1), the 64-m antenna servo boresighting system, antenna gain measurements, etc. A previous article (Ref. 2) discussed the development and performance of a new constant law detector. This new detector has a wider dynamic range and a more accurate square law response than has been available in the past. Other desirable characteristics of this detector are high-level dc output with immunity to ground loop problems, fast response times, ability to insert known time constants, and good thermal stability. Conventional detectors have an accuracy on the order of 10% whereas the new detector described in Ref. 2 is a 3% instrument. This article discusses further development work which allows the operation of this detector in a programmable system that accounts for detector deviation from square law response to yield an instrument whose accuracy is better than 0.3%.

II. Calculator Applications and the Correction Factor

The increasing use of automatic machines for data acquisition, computation, control, and automation has led to a desire to adapt detectors and other instruments for operation with automatic digital equipment. Part of the development work described in the previous article

(Ref. 2), for example, fast response times and high-level dc output with immunity to ground loop problems, etc., was directed toward detector operation in computer-oriented systems. This article shows how the new detector can be operated in a programmable system with a ten-fold increase in accuracy.

The accuracy of the detector can be increased by accounting for the detector's deviation from square law. If the output voltage of the detector is designated V, then a correction factor α may be included by multiplying the square of the output voltage by the correction factor and by using this term in addition to the output voltage. Thus,

$$\text{corrected output voltage} = V + \alpha V^2 \qquad (1)$$

Nonlinearity effects, i.e., deviations from square law, can be accounted for to a large extent by using Eq. (1). With automatic digital equipment it is easily possible to determine and to use the optimum value for the correction factor.

III. Measurements

In order to make a complete set of test measurements on a detector under controlled conditions, an automatic system was designed and set up in the laboratory. The objective of these tests was to exercise the detectors over a wide dynamic range, to investigate the effects of varying correction factors, and to determine the accuracy of a (corrected) detector with the maximum possible accuracy. The test circuit was based on the measurement system of the previous article (Ref. 2), where a high-power broadband noise source was fed through a variable attenuator and a measured 1-dB step. The output from this step switch was connected to the input of the detector and the output was monitored in the usual way. The detector was taken over the whole of its output voltage range (0 to 2 V) by adjusting the variable IF attenuator. Each measurement point was determined by switching the same 1-dB step in and out. The response of a perfect detector would yield a set of points which, when plotted on a graph of deviation from square law versus output voltage, would be a line parallel to the abscissa and cutting the ordinate at the 1-dB point.

In order to avoid contaminating the data with human error and to avoid using an excessive amount of time in evaluating a detector, the measurement system was automated by using a desk calculator and a coupler/controller. The automatic measurement system is shown in Fig. 1.

The coupler was a Hewlett-Packard 2570A Coupler/Controller, which formed an output/input interface for the Hewlett-Packard 9100A calculator. The combination of the detector's voltage-to-frequency converter and the counter gave a binary coded decimal (BCD) input, as shown in the diagram. BCD output codings were then used to switch the 1-dB step pad in and out of the circuit, and also to start the motor drive on the IF attenuator.

The sequence of measurements that were made was as follows:

(1) Adjust the IF attenuator to set the noise power level to be detected.

(2) Switch the 1-dB pad out.

(3) Measure the detected output level.

(4) Switch the 1-dB pad in.

(5) Measure the detected power level.

(6) Compute the Y factor for three values of correction factor.

(7) Reset the power level and repeat the sequence.

If V_2 is equal to the averaged voltage at the detector output with the 1-dB pad out and V_1 is equal to the averaged voltage at the detector output with the 1-dB pad in, then

$$Y = \frac{V_2 + \alpha (V_2)^2}{V_1 + \alpha (V_1)^2} \qquad (2)$$

where α is the correction factor.

The Y factor was computed and plotted in dB, as shown in Fig. 2, for three values of α. The Y factor, or difference in dB between the measurement with the pad in and out of circuit, is plotted along the ordinate, and the detector output voltage is plotted along the abscissa. The dashed curve shows the detector characteristic when the correction factor is set equal to zero. The solid curve was computed for $\alpha = 0.035$, and the dots show the curve for $\alpha = 0.037$. This figure clearly shows the improvement in linearity to be obtained when a suitable correction factor is used. The figure also shows the sensitivity of the detector characteristic to small changes in the value of the correction factor.

Measurement repeatability was found to be good. If a specific pair of voltage measurements is repeated, the calculated value of the 1-dB pad repeats within ± 0.002 dB.

The Y factor on the ordinate of Fig. 2 is the measured value of the nominal 1-dB pad for various values of detector output voltage. It may be seen from the figure that with $\alpha = 0.035$ the detector unit number RFT470 measured the 1-dB pad as 0.938 dB. This step pad was checked with independent measurements against a National Bureau of Standards (NBS) attenuator (Ref. 3) and found to be 0.942 $\pm$0.001 dB. Since the NBS attenuator was calibrated with a CW signal at 50 MHz, and the input in this case was broadband noise (10-MHz bandwidth) centered at 50 MHz, it is possible that some of the discrepancy may be attributed to a frequency sensitivity in the NBS attenuator.

It may be seen from Fig. 2 that the detector linearity holds within 0.005 dB (i.e., 0.12%) from about 0.1 to about 2.6 V. This is a dynamic range of approximately 15 dB with an accuracy of 0.005 dB. The dynamic range may be extended to greater than 20 dB with a slightly reduced accuracy. On the other hand the high accuracy dynamic range may be extended at the low output level end to less than 0.05 V output without impairment to the accuracy by setting in the correct dc offset. The reason for an offset requirement is because of a small difference between the dc and the voltage-to-frequency outputs. The offset in Fig. 2 was 82 μV. Another technique is to account for the offset by adding a constant term to Eq. (1).

Figure 3 shows the effect of varying offsets and correction factors for the same detector unit as used in Fig. 2. The correction factors are 0, 0.035, and 0.07. The solid curves were computed with a dc offset of 120 μV, the dashed curves with 59-μV offset, and the dots are the points with zero offset. It may be seen from Fig. 3 that the effect of the dc offset is to change the shape and position of the curve but only at the low-voltage end of the detector's dynamic range.

IV. Conclusions

A previous article (Ref. 2) discussed the development and performance of a new constant law detector with a 3% accuracy over a dynamic range of at least 15 dB. This article has shown that when this detector is used in a system with automatic digital equipment so that a large number of calculations can be performed quickly and efficiently, the accuracy can be improved by a factor of more than 10. A subsequent article will discuss the use and performance of this detector in a noise-adding radiometer.

References

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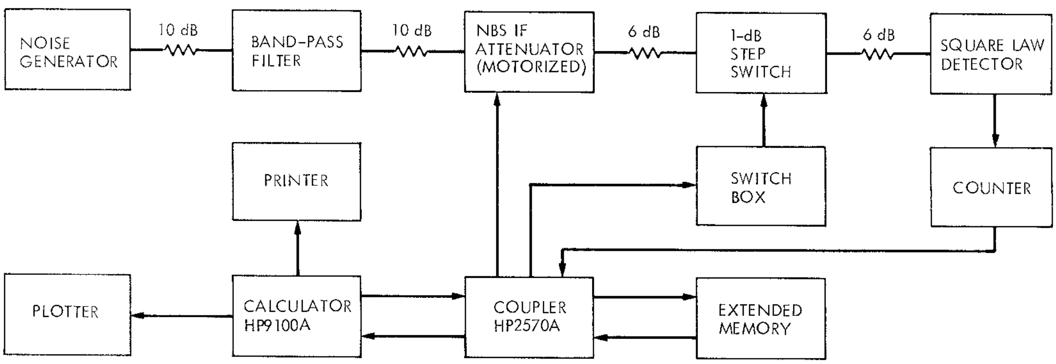

Fig. 1. Automatic measurement system

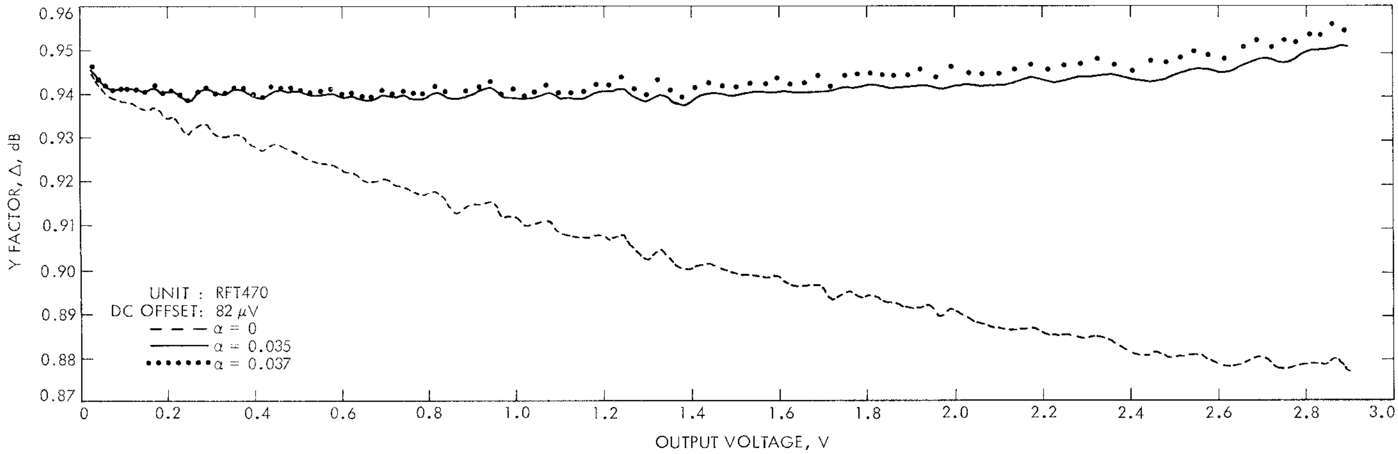

Fig. 2. Detector characteristic for three values of correction factor

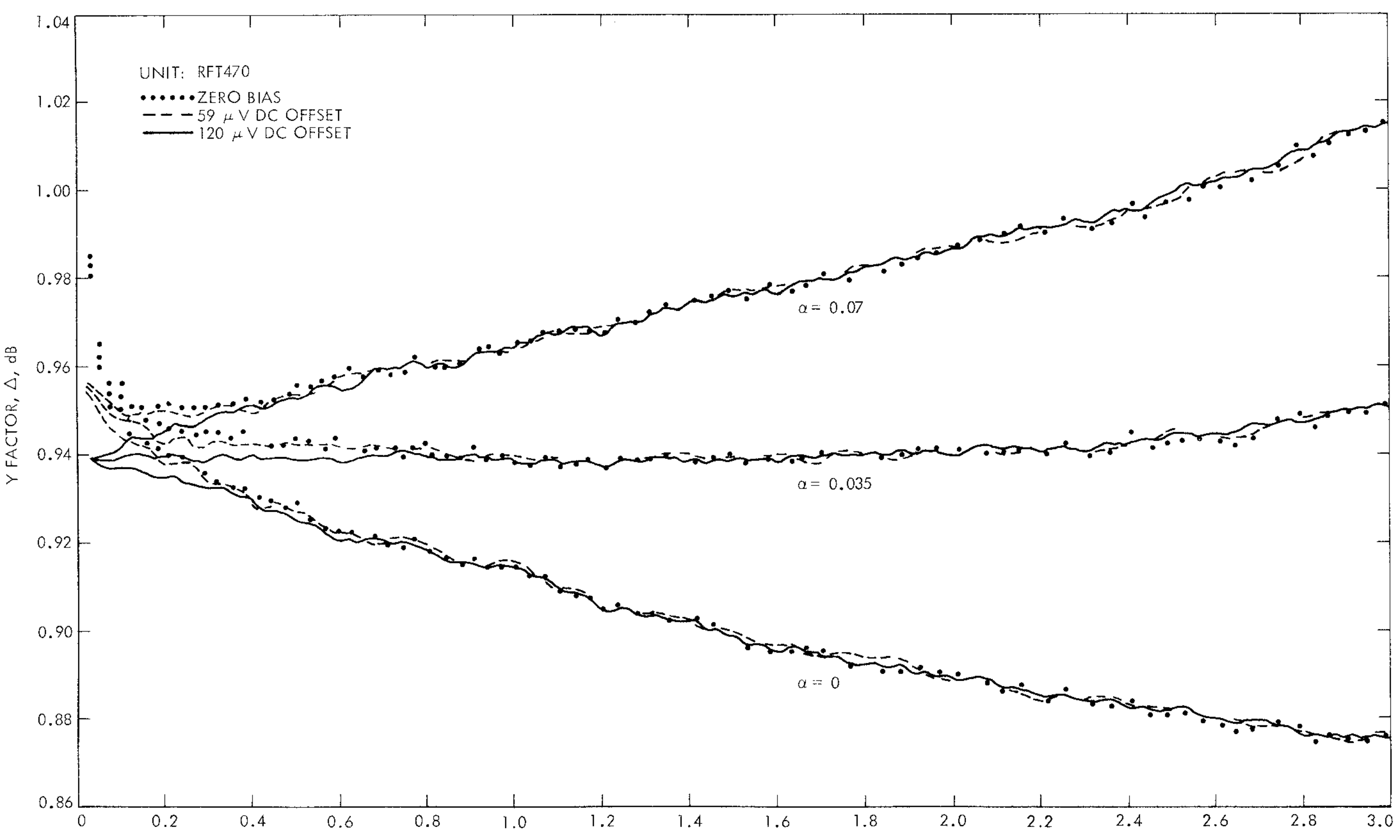

Fig. 3. Detector characteristic for various correction factors and offsets